Wardle (T.) On the Relation of Design to such Craft Teaching as may be undertaken by Technical Schools. 4to. *Manchester* 1893. The Author.

Photogravure Portrait of Professor Michael Foster, Sec. R.S., after a painting by H. Herkomer, R.A.
The Subscribers to the Foster Portrait Fund, Trinity College, Cambridge.

January 25, 1894.

Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "On Intra-cranial Pressure. Preliminary Note." By Leonard Hill, M.B., Assistant Professor of Physiology, University College, London. Communicated by Professor Burdon Sanderson, F.R.S. Received November 16, 1893.

(From the Physiological Laboratories of Oxford and University College.)

My purpose in the following note is to submit to the Royal Society the results of experiments, made during the past year, relating to the "intra-cranial pressure" (*i.e.*, the pressure to which the brain is normally exposed in the cranial cavity), and the changes which can be produced in it by alterations of the form and diminution of the capacity of the cranial cavity.

The experiments were undertaken at the suggestion of Professor Burdon Sanderson, and have been carried out with his help and criticism.

The animals employed were cats or dogs. Ether, chloroform, and morphia were used as anæsthetics.

Methods of Research.

Methods of Producing Alterations of Pressure within the Subdural Space.—

α. The skull is trephined in the parietal region, the dura mater freely divided, the trephine hole "wormed" with an ordinary

mechanic's tap, and a brass tube of about 2 inches in length screwed into the hole. This tube is connected with a burette containing salt solution at the temperature of the animal. A clip is interposed between the burette and the brass tube, and the burette connected with a pressure apparatus.

By this method salt solution can be driven into the subdural space in measured amounts and at varying rates.

β. If, before introducing the brass tube, a bag of very thin india-rubber is tied on to the end of it (the arrangement being otherwise the same), measured amounts of salt solution can be repeatedly introduced or withdrawn from the bag within the subdural space.

2. *Measurement of the Normal Intra-cranial Pressure or Cerebral Tension.*—

α. A trephine hole is made, "wormed," and filled with warm salt solution. A piece of brass tube is screwed in, over the end of which a membrane of very thin india-rubber has been tied. The brass tube is connected with the intervention of a piece of fine-bored glass tubing with a T-piece, one branch of which leads to a pressure bottle, the other to a mercurial manometer. The apparatus is completely filled with water, excepting that a bubble of air is introduced within the glass tube so as to act as an index.

The normal position of the air index is marked on the glass tube before the apparatus is screwed into the trephine hole. On screwing the apparatus in, the air index, which is at first forced out, is brought back again to the normal position by raising the pressure bottle. The manometer records the normal intra-cranial pressure.

β. A trephine hole is made and "wormed," and the dura mater is then freely divided.

The measuring apparatus is filled with 0·6 per cent. salt solution, instead of water, and an air index is introduced within the glass tubing. No membrane is placed upon the end of the brass tube, so that when the tube is screwed in its cavity freely communicates with the subdural space. The pressure bottle is now raised till the air index begins to move inwards. The manometer records the pressure which is necessary to balance the normal intra-cranial pressure. Any excess drives salt solution into the subdural space.

3. *Measurement of the Variations of Intra-cranial Pressure produced by the above Methods* (1 α and β).—

With the measuring apparatus (2 α) the variations can be accurately measured and recorded graphically. For when by increase of intra-cranial pressure the air index is displaced outwards it can be brought back again to its initial position by raising the pressure bottle to the required amount, and when by decrease of intra-cranial pressure the air index is sucked inwards it can, in like manner, be brought back again to the mark by lowering the pressure bottle. In

either case, the pressure required, as indicated by the mercurial manometer, is the intra-cranial pressure at the time.

4. *Methods of obtaining Records of the Cerebral Venous Pressure.*—The superior longitudinal sinus, with its tributaries, in the dog opens into a large venous cavity within the occipital protuberance; the transverse sinuses lying within the bony tentorium cerebelli lead out of this cavity. Part of the blood finds its exit by the post-glenoid foramen, and reaches the external jugular vein, but a very large portion passes into the large sinuses which run down the vertebral canal.

The methods are as follows:—

α. A hole is drilled into the venous cavity within the occipital protuberance. Into the hole a tube is fixed, filled with sodium sulphate solution. The tube is connected with a water manometer.

β. The skull is opened over the occipital protuberance, and a venous cannula passed into the superior longitudinal sinus against the direction of the blood flow. The cannula is connected with a water manometer. This method gives the venous pressure with obstructed flow.

In either of these methods the manometer can be connected with a light and delicate tambour, and the venous pressure recorded.

Records of the blood pressure in the carotid artery, and of the respiration, were taken simultaneously with the records of intra-cranial pressure.

By the method of "worming" the trephine holes before screwing in the brass tubes the connexions were made (as tested) absolutely air tight. The delicacy of the measuring apparatus was tested on an artificial scheme, and found to be perfect.

Results.

1. The normal intra-cranial pressure scarcely ever exceeds 10 mm. Hg. (Method 2 *α* and *β*.)

2. The normal cerebral venous pressure in the dog is equivalent to 100—120 mm. water. (Method 4 *α*.)

3. The pressure in the superior longitudinal sinus with the flow of blood obstructed rises to double or more the normal cerebral venous pressure. (Method 4 *β*.)

4. The air index in the measuring apparatus exhibits perfectly the cardiac and respiratory undulations of the intra-cranial pressure. (Methods 2 and 3.)

5. The water manometer in connexion with the venous cavity in the occipital protuberance, or with the longitudinal sinus, exhibits the cardiac pulsations and large respiratory undulations. (Method 4 *α* and *β*.)

6. Salt solution (0·6 per cent.) can be slowly driven into the subdural space at the rate of about 1 c.c. a minute, without raising the intra-cranial pressure or producing any physiological effects. As much as 20 c.c. has thus been driven in during one experiment. (Method 1 α.)

7. Salt solution can be driven through from the parietal hole to a hole in the lumbar region of the spinal column. The whole of the subdural space can thus be syringed through.

8. Salt solution cannot be driven from a hole in the lumbar region out of a hole in the parietal region. The brain floats up and closes the parietal hole as a valve.

9. Salt solution, if driven in quickly with a higher pressure, produces a momentary rise of intra-cranial pressure and momentary physiological effects. These disappear very rapidly as the solution is absorbed.

10. On introducing 0·5 c.c. of salt solution within a bag in the subdural space of a cat (Method 1 β), no rise of intra-cranial pressure occurs, and no physiological effects are produced.

11. The introduction of more than 0·5 c.c. produces a lasting rise of intra-cranial pressure and physiological effects. These are: (1) slowing to stopping of respiration; (2) rise of blood pressure and slowing of the heart; (3) dilatation, or extreme constriction, of the pupil, and sometimes nystagmus.

12. The cat may become habituated to the smaller degrees of heightened intra-cranial pressure, and the physiological effects pass off.

13. Greater amounts than 1 c.c. cause an enormous and maintained rise of arterial pressure, with acceleration of the heart, inspiratory gasps at long intervals, followed by fall of arterial pressure and death.

14. 0·5 c.c. is the largest amount of displacement which can be perfectly compensated for in the cat, *i.e.*, this is the reduction of the cranial capacity which can be made up for by escape of cerebro-spinal fluid.

15. The brain of the cat of ordinary size, measured up to the level of the calamus scriptorius, equals in volume 26 c.c.

16. The amount of compensation is reduced to nothing on repeating the experiment a second time, and the effects which follow the introduction of the same quantity of salt solution into the bag are much more marked.

17. In the dog of the fox-terrier size the amount of compensation is 1·5 c.c.

18. The brain of the ordinary fox-terrier, on an average, equals 64 c.c. in volume.

19. The introduction of more than 1·5 c.c. in the dog produces

a lasting rise of intra-cranial pressure and physiological effects. These are the same as in the cat, except that there is no rise of blood pressure.

20. On cutting both vagi in the dog, the rise of blood pressure occurs as in the cat, and may reach enormous amounts.

21. The compensation is reduced to nothing in the dog on repeating the experiment a second time, and the effects are much more severe.

22. The physiological effects can be immediately removed by emptying the bag, and the pressure in the intra-cranial cavity recovers its old standard.

23. If the displacement caused by the bag is large, and maintained for a considerable time, there may be no relief and no expansion of the brain on emptying the bag.

24. Trephine holes made in various parts of the cranium and vertebral column afford no relief to the effects produced by the bag.

25. No fluid is to be found within the subdural space after the "bag experiment." The surface of the brain and the cavity of the skull are quite dry.

26. After the "bag experiment," salt solution (Method 1) can no longer be absorbed, and can no longer be driven through to a hole in the lumbar region, but acts in the same way and produces the same effects as the bag.

27. Marked physiological effects occur in the cat when the intra-cranial pressure is raised 10 mm. Hg above the normal. The measurement is taken over the medulla oblongata.

28. The venous pressure in the cavity of the occipital protuberance falls to zero when the "bag" is distended over the parietal region, *i.e.*, the entrance of blood is obstructed; the exit by the bony transverse sinuses remains open. (Method 4 α.)

29. The venous pressure in the superior longitudinal sinus rises when the "bag" is distended, *i.e.*, the exit is obstructed by the cannula, and blood is forced out of the tributary veins into the sinus. (Method 4 β.)

30. The normal venous pressure in each case at once returns when the bag is emptied.

Conclusion. November 18, 1893.

The capacity of the intra-cranial cavity can be diminished by the introduction of a foreign body into the subdural space. The first effect of the diminution is to expel the cerebro-spinal fluid. After its disappearance, further diminution of the space can only take place by equal diminution of the volume of the intra-cranial blood vessels, particularly of the veins and capillaries. *The* restriction or *arrest of the cerebral circulation thus produced is the efficient cause of the physio-*

logical disturbance observed after diminution of the intra-cranial cavity.

In the animals experimented on, any considerable increase of the intra-cranial pressure above the normal (about 10 mm. mercury) interferes with or arrests the cerebral circulation.

A further Result. November 27, 1893.

On driving salt solution coloured with methyl blue into the subdural space at the rate of 1 c.c. a minute, the urine which was collected from one ureter became of a blue colour in from 15 to 30 minutes. On *post-mortem* examination, the upper portion of the first lymph gland in the cervical chain was found to be coloured blue; in the central nervous system the blue colour was found limited to the cerebral hemisphere on the side of injection, the base of the brain, and the cervical region of the cord. Conclusion—The blood vessels form the pathway of absorption of fluid from the subdural space.

The expenses of the above research have been partly defrayed by a grant from the British Medical Association.

II. "Experimental Researches into the Functions of the Cerebellum." By J. S. Risien Russell, M.D., M.R.C.P., Assistant Physician to the Metropolitan Hospital. Communicated by Professor Victor Horsley, F.R.S. Received December 14, 1893.

(From the Pathological Laboratory of University College, London.)

(Abstract.)

The views that have been expressed as to the probable functions of the cerebellum are briefly alluded to, and the results obtained by previous investigators, as the direct outcome of experimentation, are detailed at greater length.

The objects of the present research were to determine :

1. Whether each lateral half of the cerebellum is capable of acting independently, or whether it is necessary for the connexions between the two halves to be intact, in order that the functions of the organ should be properly performed.

2. If impulses pass from one side of the organ to the other before they are transmitted to the cerebrum or spinal cord.

3. What is the nature of the impairment of movement which results when portions of the organ are removed.

4. What relationship exists between one half of the cerebellum